

Measurement of the ATLAS di-muon trigger efficiency in proton-proton collisions at 7 TeV



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At the LHC, muons are produced in many final states and used in a variety of analysis, such as Standard Model precision measurements and searches for new physics. The B-physics programme in ATLAS includes the measurement of CP violating effects in B meson decays, the search for rare b decay signatures, as well as the study of the production cross sections. The ATLAS detector can identify muons with high purity in a transverse momentum (p_T) range from a few GeV to several TeV. In order to achieve a high trigger efficiency for low p_T di-muon events and at the same time keep an acceptable trigger rate, dedicated trigger algorithms have been designed and implemented in the trigger menu since the 2010 data taking period. There are two categories of B-physics triggers, one topological and one non-topological. Both of these have been studied and their performance assessed using collision data at $\sqrt{s} = 7$ TeV. The performance found with data has been verified with simulated events.

I. DI-MUON TRIGGER IN ATLAS

At the design luminosity of $10^{34} \text{cm}^{-2}\text{s}^{-1}$ the LHC's bunch crossing rate is 40 MHz at each of the four interaction points (ATLAS, CMS, LHCb, ALICE). The ATLAS trigger system is designed to reduce this rate, and record events at approximately 200Hz. In order to reduce the rate the system is made of three levels. The Level 1 (L1) is hardware based and uses information from the calorimeter and the fast muon trigger detectors at reduced granularity. L1 reduces the input rate to a maximum of 75 kHz (30 kHz in 2010) and also identifies Regions of Interest (RoIs) that are then investigated by the other levels. The Level 2 (L2) and the Event Filter (EF) are software based and use information from all the subdetectors. Together they are known as the High Level Trigger (HLT). L2 reduces further the rate to about 3 kHz. The final reduction is done at the EF [1].

To achieve this large rate reduction a p_T threshold must be raised and interesting low p_T events are lost. Therefore ATLAS has developed di-muon triggers with lower muon p_T thresholds. These allow events of interest for the B-physics community to be recorded. This choice accommodates both the rate reduction as well as a high efficiency at the HLT.

B-physics triggers can be divided into two categories (illustrated in Figure 1), depending on the algorithm used at L2 to select the di-muon pair. The TrigDiMuon triggers are seeded by a single L1 muon RoI. The HLT algorithm then searches for a second

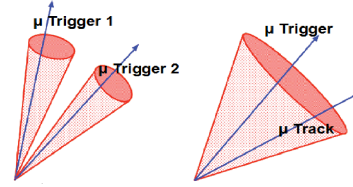


FIG. 1: Diagram showing how the two different B-physics trigger algorithms are configured. The diagram on the left shows a generic topological trigger, the one on the right shows the TrigDiMuon trigger.

muon within a wide η , ϕ region, where η is the pseudorapidity and ϕ the azimuthal angle. This is done by extrapolating Inner Detector (ID) tracks to the muon spectrometer. The extrapolation can also be done by looking into the whole detector, however this strategy is not followed in this poster. The second category are the topological di-muon triggers which are seeded by two L1 muon RoIs. Each muon is then confirmed separately at the HLT.

Both categories of triggers apply extra requirements in invariant mass, opposite charge and vertex χ^2 match in order to reduce the rate and yet keep interesting J/ψ , Υ and B meson data.

As an example, the di-muon triggers studied below have the `_Jpsimumu` extension in their name. This refers to the hypothesis which in this case is summarised as follows:

- Oppositely charged muon trigger objects;

- Invariant mass in the range from 2.5 GeV to 4.3 GeV;
- Vertex χ^2 match < 20 ;

II. TRIGGER EFFICIENCY MEASUREMENT FOR DI-MUON TRIGGERS FROM 2010 DATA AND MONTE CARLO COMPARISON

The accurate determination of the trigger efficiency is of great importance for precise cross section measurements in the low energy regime. In fact the p_T spectrum of muons from J/ψ and Υ decays is soft and populates the low trigger threshold region.

Offline, the selection of two oppositely charged combined muons with invariant mass in the range from 2.8 GeV to 3.34 GeV minimizes the background contamination and selects a pure J/ψ sample. The trigger efficiencies determined below are measured with respect to this class of muons.

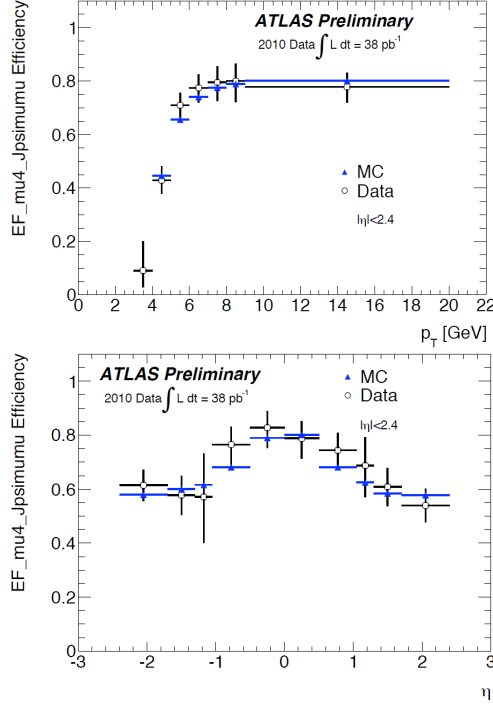


FIG. 2: Efficiency of EF_mu4_Jpsimumu as a function of the p_T (top) and η (bottom) of the reconstructed muon with higher p_T in the di-muon pair [2].

The method presented in the poster is based on Bayes' theorem. According to this, the efficiency of a di-muon trigger can be expressed as

$$\varepsilon(B) = \frac{\varepsilon(A)\varepsilon(B|A)}{\varepsilon(A|B)} \quad (1)$$

where $\varepsilon(B)$ is the trigger efficiency of the di-muon chain and $\varepsilon(A)$ is the efficiency of single muon trigger, i.e. EF_mu4 which is an EF single muon trigger passing the 4 GeV transverse momentum threshold. The two extra factors $\varepsilon(B|A)$ and $\varepsilon(A|B)$ are the conditional efficiency terms.

The efficiency of single muon trigger has been measured in early 2010 data using the standard “Tag and Probe” method and compared to Monte Carlo simulation [3]. Also, the conditional probability can be measured from data without biasing the measurement.

By combining the various studies together, the efficiencies of various di-muon triggers have been measured using the above method in 2010 data corresponding to an integrated luminosity of 38 pb^{-1} . A good agreement with Monte Carlo simulation has been found.

Figure 2 shows the efficiency of the TrigDiMuon chain EF_mu4_Jpsimumu as a function of the transverse momentum (top) and rapidity (bottom) of the leading reconstructed muon in the di-muon pair. An example of trigger efficiency for the topological trigger EF_2mu4_Jpsimumu is shown in Figure 3. Here the efficiency is plotted as a function of the p_T of the leading reconstructed muon in the di-muon pair.

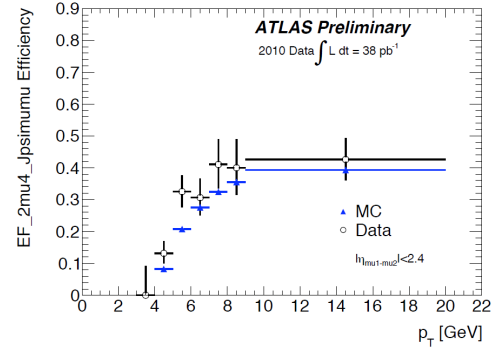


FIG. 3: Efficiency of EF_2mu4_Jpsimumu as a function of the p_T of the reconstructed muon with higher p_T in the di-muon pair [2].

By comparing the efficiency curves as a function of the transverse momentum, it is evident that at any given p_T , the efficiency of the topological trigger (Figure 3) is much lower than the corresponding efficiency for the non-topological trigger with same hypothesis (top plot in Figure 2). This is due to the difference at L1 between the two trigger algorithms. Infact the topological trigger requires two L1 seeds, therefore the overall efficiency is proportional to the square of the single seeded corresponding trigger.

- [1] The Atlas Collaboration, *Expected Performance of the ATLAS Experiment*, arXiv:0901.0512 CERN-OPEN-2008-020
- [2] *Muon Trigger Public Results*, <https://twiki.cern.ch/twiki/bin/view/AtlasPublic/MuonTriggerPublicResults>
- [3] The Atlas Collaboration, *A measurement of the ATLAS muon reconstruction and trigger efficiency using J/ψ decays*, ATLAS-CONF-2011-021, <http://cdsweb.cern.ch/record/1322421>